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Scaffolds to support the development of scientific skills in physics

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Scaffolds to support the development of scientific skills in physics

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Abstract. This paper responds to the social demand to equip learners with the skills capable to create solutions that are sustainable over time, to increasingly complex problems. To this end, this study designed implemented and evaluated an instructional process aimed to students' development of scientific skills during the scientific inquiry process. A quasi-experimental study was designed in which participated 61 university students of physics university course participated in the study. The results show that the students of the experimental group developed higher level of scientific skills than the control group.

1. Introduction

The teaching of science is fundamental to make people aware of the vision of a sustainable society and educators must help to promote the changes necessary to achieve it. In this regard, according to [1], education should help people develop the knowledge, skills and attitudes necessary to achieve sustainable development.

In this sense, pedagogical aids can be a useful tool for teachers to achieve in students the development of scientific skills, which allow them to face situations of their daily lives. In this regard, the research question under investigation in this study is: What is the impact of the scaffolds designed in the study on students' development of scientific skills?

2. Theoretical framework

To answer the research question, this study is supported by two theoretical axes; the first one is the scientific inquiry, which according to [2] plays an important role in the teaching and learning of science because it requires students to activate theoretical knowledge, scientific skills and social attitudes to solve problems. In addition, according to [3] teaching through inquiry generates teaching and learning situations that promotes students' development of a mindset related with the skills and the ways of knowledge building in science.

The second theoretical axe is a sociocultural perspective of learning [4], in which learning is explained through the interaction processes that takes place among students and teacher and the quality of the scaffolds that are provided and the scaffolding processes created during learning. The term "scaffolding" was used for the first time by [5] and it refers to a structure of aids designed to accompany the student from the beginning of the learning process, but It will be gradually dismantled until it disappears when the student is able to perform the desired task on his/her own. In this regard, there are different modalities and types of scaffolding depending on the audience and the available resources.

2.1. Science Process Skills
An essential part of the development of the process of inquiry is based on the ability of people to apply scientific skills in the search and interpretation of evidence to solve a problem [6]. Therefore, it can be said that the ability of a scientist to generate knowledge depends on their ability in each of the aspects that make up the scientific task.

Therefore, scientific skills can be defined as the ability to establish complex and organized thinking and/or action schemes to achieve an objective [7]. Therefore, they are considered indispensable tools for scientists to form a knowledge base based on the solution of a problem [8].

From science education the main objective should be for students to develop scientific skills, as it will provide them with tools they will use to build scientific concepts to understand the world around them [9]. In addition, it will provide the student the ability to apply the acquired knowledge in their daily environment, that is, it will allow them to make informed decisions about the problems that affect their family environment and their community [10].

Taking this into account, a review of the research (2013-2017) was carried out in which they set out different stages or stages to develop the inquiry process [11], [12], [13], [14], [15], [16]. As a result, the following phases are proposed in the present investigation: establish the problem, design the experiment, collect data, process data, draw conclusions and disseminate the research.

Finally, from these phases and considering the proposals of researchers such as [17], the scientific skills that university level students should develop during the inquiry process were established, so that they can reach the conceptual understanding of physical models, and consequently, to be able to solve problems in real contexts.

2.2. Scaffolding
[6], expresses that scaffolding is a very convenient term to refer to the way in which students are helped to take the next step in the understanding of concepts, which is very present at the beginning of the learning process when they incorporate new concepts, which in the case of science education could be to solve a situation-problem in an autonomous way. In this sense, for [18], pedagogical aids from sociocultural theory must occur during the student-student or student-teacher interaction through instruments or symbols directly or indirectly, which in a broader sense it is known as dialogue.

2.2.1. Scaffolding Modalities
Deepening the way in which pedagogical aids are given within the classroom, it can be said that these depend mainly on the people who intervene and on the available resources. In this regard, [19], has identified three modalities in which this occurs:

- One-to-one scaffolding: it is considered the most common modality, since they are the aids that the teacher provides to each student and usually adapts very well to their individual needs, therefore, the success of this modality depends of the teacher's ability to continually diagnose the student's abilities [19].
- Peer scaffolding: are the aids that are given between classmates, usually in pairs or in small groups and the role of the teacher is to promote the construction of structures that promote participation and continuous dialogue among participants [19], because when students have the same level of knowledge about a subject, they have difficulty expressing what they know to their classmates (King (1998), Mercer, Dawes, Wegerif, & Sams (2004), cited in [19]).
- Computer/paper-based scaffolding: are the aids that are given through computers or any other material that serves as support to the interactions that take place inside or outside the classroom [19]. Within the classroom, it can promote discussions during the resolution of problems [20], or to facilitate the acquisition of skills during the development of an experimental activity, and outside the classroom it is common for it to be used for transmit information through tutorials.

It should be noted that combinations between these modalities can also be given according to the needs of the audience or the available resources. For example, when an activity is carried out based on the use of the computer in the classroom (computer-based scaffolding), the teacher must simultaneously "walk" through the classroom to give help (One-to-one scaffolding) to students who they need it [19].

2.2.2. Scaffolding types
Just as there are scaffolding modalities, different scaffolding types have also been proposed, such as: Conceptual, Metacognitive, Procedural, Strategic [21] and Techniques [22].

- Conceptual scaffolding: allow students to understand a complex problem or to clarify misconceptions through the use of maps, diagrams or direct advice from the teacher or a classmate [23]. In addition, they are designed to support students in establishing the underlying conceptual bases of the problems, with the purpose of constructing arguments, monitoring and evaluation during the resolution process [24].
- Metacognitive scaffolding: aimed at the internal processes of students to promote reflection and evaluation of their conceptual understanding, in addition to providing support in the supervision of their problem-solving processes [25]. The teacher can implement this help through activities that encourage discussion and analysis of the arguments of students in small groups or the whole classroom.
- Procedural scaffolding: help provided to students to take advantage of available tools and resources, in order to find the most appropriate procedures to solve a problem [23]. So, as they learn different procedures, students will be able to create their own and thus be able to overcome new problems effectively [24].
- Strategic Scaffolding: focuses on developing planning skills to solve problems effectively, such as: critical thinking, strategic planning, decision making, construction of arguments and evaluation of the whole process [24]. Likewise, these aids induce the students to value other ways of solving problems taking into account the arguments of the classmates or the suggestions of the teacher.
- Technical scaffolding: originally they were provided aids through the use of a computer [22]. However, they can currently be implemented using different electronic devices such as tablets [26] or smartphones [27].

It should be noted that, like the modalities, the different types of aid can be combined, especially when the implementation is carried out in an environment that requires a deep intervention, that is, in which a certain amount of results is sought in a short period of time

3. Methodology
A quasi-experimental methodology was designed, with a control group who followed a traditional physics classes, and an experimental group that participated in a challenge-based learning. The instructional process consisted of solving a challenge in which students had to answer the following question: With what angle is the greatest horizontal distance reached in a movement in two dimensions?
In order to solve this challenge, students should follow the phases of scientific inquiry. The instructional process focused on supporting this process by giving specific scaffolds such as: demonstrations and classroom experiments (conceptual and metacognitive scaffolding), computer simulations and the analysis of videos of the experiment (procedural, strategic and technical scaffolding).
Likewise, to evaluate the level of development of scientific skills, an evaluation test was designed and applied before and after the intervention. This test was related with an experimental problem about the experimental determination of the elastic constant of a spring, description and data in the form of a

table was provided. Students had to answer ten questions related to the phases of problem statement, experimental design, data processing and drawing conclusions.
Subsequently, coding scheme was elaborated in order to study the scientific skills used by students to solve the problem. This coding scheme is based on the one elaborated by [17] and it relates the scientific skills with different level of cognitive complexity (Figure 1). In this way, a scale from 1 to 4 was created, where 4 corresponded with an advanced skill level, 3 integrated, 2 intermediate and 1 rudimentary.

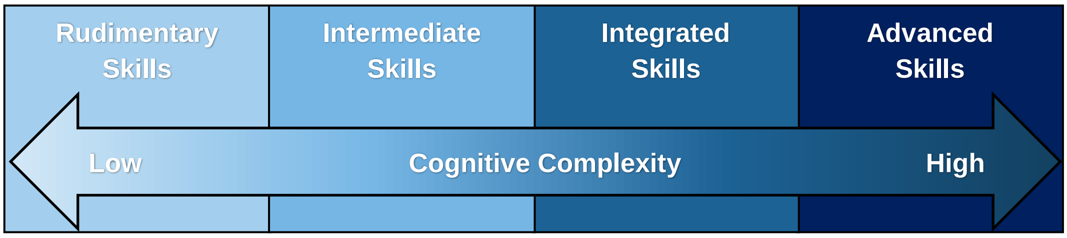

Figure 1. Classification of scientific skills according to the degree of cognitive complexity. Adapted from [17].

4. Results
In the pre-test (Figure 2), 86.8% of the students in the experimental group and 95.7% in the control group had a rudimentary level of scientific skills. While, in the post-test 55.3% of the students in the experimental group reached an intermediate level and 82.6% of the control group remained at a rudimentary level.
Therefore, it can be said that the students of the experimental group developed a higher level of scientific skills than the control group. In this regard, previous studies have shown that when students participate in teaching-learning processes of guided inquiry, they acquire greater autonomy [28] [29] [30], so they develop more scientific skills. Specifically, in the present investigation this process of inquiry was closely related to the application of different types of scaffolding, through the experimental activities and the use of ICT.

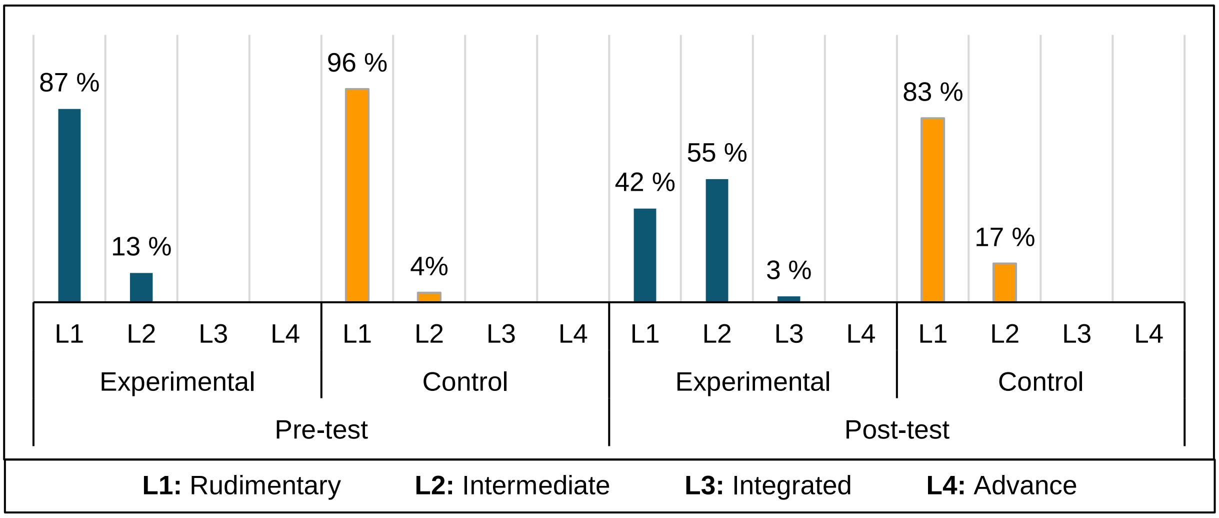

Figure 2. Students' level of scientific skills, before and after the intervention.

5. Discussion
The results obtained by the students of the experimental group suggest that the different types of scaffolds designed in our study helped students' development of scientific skills. On contrary, the control group that followed a more traditional teaching methodology in physics did not develop these

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scientific skills. Therefore, our study opens up a promising path in introducing teaching methodologies in physics that focus on: challenge-based learning and the design of appropriate scaffolds to support the skills involved in an inquiry scientific inquiry.

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